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## DISEASE AND INSECT CONTROL ON HOPS

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## ABSTRACT

PRACTICALLY all New York State hop growers are confronted with the problem of controlling downy and powdery mildews, aphids, and sooty mold. Leafhoppers may also be destructive on unsprayed hop plants. Because the nature of the control measures is preventive rather than curative, they should be carried out every year to insure a full crop of highest quality hops. During the past 4 seasons it has been demonstrated in experimental and commercial yards that hops can be economically produced free of disease and insect damage. The spray schedule and other control methods presented in this bulletin are based on field experiments conducted during the past 7 years in Oneida County.

The spray schedule recommended for late varieties includes four applications of bordeaux 6–4–100 plus 4 or 5 pounds of wettable sulfur dust to control both downy and powdery mildews. Two of the applications are made in June and two in July at 15- to 20-day intervals. One pint of nicotine sulfate is added to the bordeaux-sulfur mixture when it is necessary to control aphids.

Sooty mold is controlled on late varieties with two applications of nicotine sulfate, the first application at the time of the last bordeaux-sulfur spray, and the second, comprising a mixture of the nicotine sulfate with soap, just before harvest.

Early varieties of hops are sprayed the same as late varieties, except that spraying is begun a week earlier and is finished about 2 weeks earlier, so that the last bordeaux-sulfur application is made when the cones begin to grow out from the bur stage. The second nicotine sulfate spraying for sooty mold is seldom needed on early varieties.

It was found that hop diseases and insects are controlled more effectively and more economically by liquid spraying than by blowing the chemicals onto the plants as dusts. Dusting should not be relied upon as the chief method of attack against any of the diseases or insects of hops, whenever a sprayer is available. Dusting is a useful supplement to spraying, however, in that the chemicals can be applied quickly in case of a serious outbreak of one of the mildew diseases. A dust containing copper can be applied early in the season when the ground may be too wet to support the weight of most sprayers. Copper-sulfur dusts can be used safely on the cones, whereas the bordeaux-sulfur spray would leave an undesirable residue.

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R. O. MAGIE[1]

## INTRODUCTION

The commercial production of hops in New York State is practically impossible without adequate control of diseases and insects. Downy mildew, caused by *Pseudoperonospora humuli* (Miy. and Tak.) Wilson, is most destructive in wet seasons in nearly all hop-growing regions of the State. Some of the hop acreage in Franklin County is unique in not having experienced an epidemic of this disease. Powdery mildew, caused by *Sphaerotheca humuli* (DC.) Burr, is found in all parts of the State and is destructive in Franklin County, becoming epidemic in certain yards every year. The common hop aphid (*Phorodon humuli* Schrank) is found in all hop yards of the State during July and August. This insect usually causes no appreciable injury until late in August when conditions favor its rapid increase. The direct injury caused by the aphid is slight compared to the damage caused by the sooty mold (*Cladosporium aphidis* Thuem.)[2] which grows on the honeydew deposited in the cones by the aphids. The potato leafhopper (*Empoasca fabae* Harris) causes yellowing and killing of hop leaves and stunts the growth of vine and cone. Extensive leafhopper injury is generally found only in the smaller yards near fields of leguminous crops or weeds.

Other fungi attacking the hop in this State are *Colletotrichum humuli* Dearness and *Cylindrosporium humuli* Ell. and Ev. The hop-vine borer (*Hydroecia immanis* Gn.), the red spider, and the corn borer (*Pyrausta nubilalis* Huebner) are sometimes troublesome insects.

As a result of severe losses due to poor disease control, hop growers have rapidly replaced their dusters with power sprayers. Before 1940 only one-sixth of the hop acreage was equipped for spraying, but

[1]The writer is indebted to members of the Division of Entomology at this Station for advice and criticism on phases of insect control reported here.

[2]According to determinations by J. A. Stevenson of the United States Department of Agriculture, the *Cladosporium* present in hop cones does not appear to differ greatly from *C. aphidis*.

by 1943 about nine-tenths of the acreage was so equipped. With better control, the annual crop loss from diseases is reduced from over 30 per cent to less than 10 per cent.

This bulletin gives the results of experiments conducted in the Oneida County hop-growing area during the past 7 years on the development of efficient and economical methods of controlling hop diseases and insects.

## MATERIALS AND METHODS

Well-established plantings of the Late Cluster and "English" Cluster varieties were used in the investigations, unless otherwise stated. Liquid fungicides were applied with power spraying equipment in commercial and experimental yards between 1936 and 1943. Before 1940 each plant was sprayed individually with a gun or a broom to the point of dripping. Since 1940, except as otherwise indicated, sprays were applied thru fixed nozzles, every row being sprayed on either side as the sprayer passed along at the rate of 2 to 3 miles an hour. Three nozzles were placed on each side of the sprayer. The rate of application varied from 150 to 400 gallons per acre, according to the size of the plants.

Dusts were applied with a power duster thru six nozzles arranged to dust two rows at a time. The rate of application was about 40 pounds per acre.

Results of the disease control tests were based on the percentage of diseased leaves, stems, blossoms, or cones as well as upon the yield whenever harvesting records could be taken.

## EXPERIMENTAL RESULTS

### DOWNY MILDEW

Downy mildew is the most destructive disease of hops and the most difficult to control. Stems, leaves, blossoms, and cones of the hop plant are attacked, browned, and killed. Systemic infection of a young shoot, shown in Fig. 1, is the first symptom of the disease to appear in the spring. The major part of the hop disease research has been directed toward the control of this malady, and a report of this work appears in Technical Bulletin No. 267 of this Station.

The seasonal development of the fungus and the disease development in relation to weather conditions were studied for five seasons. With these studies as a background, economic methods of sanitation and spraying were devised to control the disease. Some new studies on downy mildew and others not fully reported in Technical Bulletin No. 267 are detailed here.

The value of sanitation in the control program was tested by removing all diseased shoots from a yard every week from May 15 to June 15 and comparing the disease development with that in a neighboring yard where no sanitation was practiced. In another season the treatments in these two yards were reversed. The number of infected leaves and shoots was materially reduced by eliminating the diseased shoots and the development of serious infection was delayed over 2 weeks, as shown in Table 1.

FIG. 1.—*Left,* HOP SHOOT OR SPIKE AFFECTED WITH DOWNY MILDEW; *right,* HEALTHY SHOOT.

During the seasons of 1937, 1938, and 1940, crown treatments were tested in controlling the infection of young shoots. The purpose of treating the crowns of dormant plants is to prevent the infection of shoots by the overwintering oospores in the soil. The chemicals were applied evenly over the soil covering the crowns 5 to 21 days before shoot emergence. Calcium cyanamid, copper-lime dust, soap bark, and a 2 per cent solution of Dowacide "F" were tested. The last-named material was toxic to the shoots. Calcium cyanamid was

TABLE 1.—EFFECT OF SANITATION IN REDUCING DOWNY MILDEW INFECTION ON LATE CLUSTER HOPS.

| YARD NO. | YEAR | TREATMENT | NUMBER OF INFECTED LEAVES PER PLANT | | NUMBER OF INFECTED SHOOTS PER PLANT | |
|---|---|---|---|---|---|---|
| | | | June 1–5 | June 15–20 | June 1–5 | June 15–20 |
| 1 | 1938 | None | 4.8 | 14.9 | 1.2 | 5.1 |
| 3 | 1938 | Sanitation | 1.0 | 3.5 | 0.5 | 0.9 |
| 3 | 1940 | None | 3.1 | 10.4 | 0.8 | 4.7 |
| 1 | 1940 | Sanitation | 0.5 | 1.1 | 0.4 | 0.7 |
| 13 | 1942 | None | 6.7 | 16.0 | 1.0 | 3.8 |
| 1 | 1942 | Sanitation | 1.2 | 4.3 | 0.4 | 0.8 |

the most effective material (Table 2). Copper-lime dust was much less effective and soap bark was ineffective.

TABLE 2.—THE EFFECT OF TREATING CROWNS WITH CALCIUM CYANAMID IN APRIL ON THE CONTROL OF EARLY SEASON DOWNY MILDEW INFECTION ON "ENGLISH" CLUSTER HOPS.

| DOSAGE PER PLANT, OUNCES | NUMBER OF PLANTS | TREATMENTS MADE IN STATED NUMBER OF DAYS BEFORE SHOOT EMERGENCE | TIME OF TREATMENT IN RELATION TO HOEING AND PRUNING OF CROWNS | INDEX OF DISEASED SHOOTS PER PLANT, MAY 22–28* | DEGREE OF INJURY |
|---|---|---|---|---|---|
| | | | 1937 | | |
| 4 | 120 | 19 | Before | 32 | Slight |
| 4 | 120 | 19 | Before | 11 | None |
| 4 | 150 | 8 | After | 15 | Medium |
| 4 | 150 | 15 | Before | 6 | Severe† |
| | | | 1938 | | |
| 2 | 47 | 21 | Before | 48 | None |
| 2 | 62 | 5 | After | 31 | Slight |
| 4 | 45 | 21 | Before | 42 | None |
| 4 | 60 | 5 | After | 20 | Medium |
| | | | 1940 | | |
| 2 | 48 | 19 | Before | 58 | None |
| 2 | 51 | 19 | After | 31 | Slight |
| 2 | 47 | 8 | Before | 42 | Slight |
| 2 | 47 | 8 | After | 14 | Medium |
| 2 | 50 | 19 | After‡ | 54 | None |
| 2 | 50 | 8 | After‡ | 34 | None |

*Rating nontreated plants at 100, index denotes relative amount of disease in treated plants.
†Severe injury might have been enhanced by poor drainage and wet soil.
‡Plants pruned in fall of previous year; soil undisturbed in spring.

The results of extensive tests of sprays and dusts made during the past 7 years are summarized in Table 3. On the basis of these and other results, bordeaux mixture and Yellow Cuprocide sprays were recommended for the control of downy mildew. Zinc sulfate plus lime and the insoluble copper sprays were as effective as bordeaux except in the protection of the cones. Silver nitrate-ferrous sulfate-lime spray, ¼–½–¼–100, was very effective in the one test. Copper and sulfur materials applied as dusts gave less control than when applied as sprays.

The addition of spreaders and stickers did not improve the performance of bordeaux or of Cuprocide sprays. The use of 0.25 per cent cottonseed oil with zinc oxide, 2–100, prevented the leaf injury caused by zinc oxide alone.

TABLE 3.—SUMMARY OF RESULTS OF SPRAYING AND DUSTING EXPERIMENTS FOR THE CONTROL OF HOP DOWNY MILDEW, 1937–43.

| SPRAY AND DUST MATERIALS* | NUMBER OF TESTS | DEGREE OF MILDEW CONTROL ON† | | | | YIELD INDEX‡ |
|---|---|---|---|---|---|---|
| | | Leaves | Vines | Blossoms | Cones | |
| **Sprays** | | | | | | |
| Bordeaux, 6–4–100 | 10 | Good | Good | Good | Good | 100 |
| Bordeaux, 3–2–100 | 6(3)§ | Good | Good | Good | Good | 102 |
| Bordeaux, 3–2–100+cottonseed oil, ¼ per cent | 4(3) | Good | Good | Good | Good | 100 |
| Bordeaux, 3–2–100+wettable sulfur, 4–100 | 4(2) | Good | Good | Good | Good | 94 |
| Cuprocide (red), 2–100 | 5(4) | Good | Good | Good | Good | 101 |
| Cuprocide (red), 1–100 | 2(2) | Good | Medium | Good | Medium | 98 |
| Cuprocide (red), 1–100+cottonseed oil, ¼ per cent** | 2(2) | Good | Good | Good | Medium | 96 |
| Cuprocide (red), 2–100+goulac, ½–100 | 2(2) | Good | Good | Good | Medium | 94 |
| Cuprocide (red), 2–100+rosin size, ½–100 | 2(2) | Good | Good | Medium | Medium | 87 |
| Cuprocide (red), 2–100+wettable sulfur, 4–100 | 2(1) | Good | Good | Good | Good | 102 |
| Yellow Cuprocide, 1½–100 | 4(1) | Good | Good | Good | Good | 97 |
| Tri-basic copper sulfate, 3–100 | 1 | Good | Good | Good | Medium | — |
| Copper oxychloride sulfate, 3–100 | 1 | Good | Good | Good | Medium | — |
| Zinc oxide, 2–100+cottonseed oil, ¼ per cent** | 2 | Good | Good | Medium | Medium | — |
| Zinc sulfate-lime, 8–6–100 | 7(6) | Good | Good | Good | Medium | 98 |
| Wettable sulfur-lime, 10–2–100 | 2(2) | Good | Medium | Medium | Medium | 82 |
| Silver nitrate-ferrous sulfate-lime, ¼–½–¼–100 | 1 | Good | Good | Good | Good | — |
| Fermate, 2–100 | 1 | Good | Medium | Good | Medium | — |
| Spergon (wettable), 4–100 | 1 | Poor | Poor | Poor | None | — |
| **Dusts** | | | | | | |
| Sulfur dust | 2(1) | Medium | Medium | Poor | Poor | 62 |
| Cuprocide (red)-sulfur dust, 7–93 | 2(2) | Good | Medium | Medium | Medium | 77 |
| Tri-basic copper sulfate-sulfur dust, 15–85 | 2 | Good | Medium | Medium | Medium | — |
| Copper-lime dust, 25–75 | 2(2) | Good | Medium | Medium | Medium | 72 |
| Untreated control | 10 | None | None | None | None | 51 |

*Three or four spray applications made at 15- to 20-day intervals, one or two in June and two in July. Five or six dust applications made at intervals of 10 to 14 days.

†Degree of mildew control is based on percentage of plant parts infected. Good = less than 2 per cent; Medium = 2 to 15 per cent; Poor = over 15 per cent.

‡Relative yield based on the yield of Bordeaux, 6–4–100, taken as 100.

§Figures in parenthesis refer to number of tests run in direct comparison with bordeaux, 6–4–100.

**Emulsified with goulac.

Bordeaux 3–2–100 was just as effective under the experimental conditions as bordeaux 6–4–100. The lower concentration cannot be recommended for general use until its effectiveness has been thoroly tested in commercial plantings.

Four applications of the bordeaux spray were sufficient for effective control in the experimental yards in the most epidemic years. In relatively dry years only two applications were needed. Sprays applied in July were most effective in controlling the disease and producing a full crop. The most effective timing of the four applications is indicated in Table 10.

### POWDERY MILDEW

Powdery mildew, or "blue mold", attacks the leaves, blossoms, and cones, producing a characteristic white, powdery growth. The white spots begin to appear on the leaves any time from early in June to the middle of July. The disease develops rapidly on the blossoms during July and on the cones during August. Infected cones are stunted and distorted, as shown in Fig. 2. Over half of the crop may be lost in unprotected yards.

The disease was controlled very effectively by applying sulfur, either as a dust or a spray. Several brands of wettable and dusting sulfurs were found to be effective. The first sulfur application should be made 3 weeks before blossoming, or before the mildew infection becomes established. All the tests show that four dustings with sulfur were sufficient, providing the first application was made before the leaf spots appeared (Table 4). To bring the disease under control, after the blossoms and cones were attacked, required several heavy applications of sulfur. Yards which have suffered recent epidemics of powdery mildew and yards within a few miles of infected hops may require additional applications of sulfur during August to protect the cones.

### APHIDS AND SOOTY MOLD

Aphids injure hop plants directly by feeding on the leaves and cones. By far the greater damage, however, is done by the mold which grows on the honeydew deposited within the cones by the aphids. Aphid populations may be built up from a few "lice" per leaf to a damaging level of several hundred within a period of 1 or 2 weeks, usually late in August. The weather generally is favorable to the development of the aphids and the mold just before or

FIG. 2.— HOP CONES STUNTED BY THE POWDERY MILDEW DISEASE.

during harvest. Part of the crop may be lost every year because of sooty mold.

Nicotine sulfate (40 per cent) at dilutions of 1–800, 1–1200, and 1–1,600 was tested in the control of aphids (Table 5). The sprays were applied with guns and the plants thoroly washed. One application of nicotine sulfate 1–800 or 1–1,200 killed over 95 per cent of the aphids in four tests. The 1–1,600 dilution killed less than 85 per cent of the "lice".

Nicotine sulfate was effective when added to bordeaux mixture or when used with any of the less expensive soaps (Table 5). One and one-half pounds of laundry soap and ¼ pound of washing soda were found to be sufficient for 100 gallons of nicotine spray; or 3 pounds of potash fish oil soap may be used for each 100 gallons.

TABLE 4.—RESULTS OF EXPERIMENTS WITH THE NUMBER AND TIMING OF APPLICATIONS OF 325-MESH SULFUR DUST FOR THE CONTROL OF HOP POWDERY MILDEW.

| DATE OF FIRST APPEARANCE OF DISEASE | DATE OF FIRST APPLICATION | NUMBER OF DUSTINGS MADE EVERY OTHER WEEK | CONES ATTACKED BY DISEASE, PER CENT |
|---|---|---|---|
| | Yard No. 10, 1938 | | |
| June 29 | June 4 | 6 | 0.1 |
| | June 16 | 5 | 0.3 |
| | July 2 | 4 | 0.6 |
| | July 14 | 3 | 12.7 |
| | July 14 | 4 | 3.7 |
| | Aug. 3 | 2 | 24.9 |
| | None | 0 | 70.1 |
| | Yard No. 4, 1939 | | |
| June 13 | June 14 | 5 | 0.3 |
| | June 14 | 4 | 1.6 |
| | June 14 | 3 | 16.3 |
| | June 29 | 4 | 3.8 |
| | June 29 | 3 | 18.1 |
| | June 29 | 2 | 44.7 |
| | None | 0 | 82.4 |

TABLE 5.—EFFECTIVENESS OF SPRAY MATERIALS AND DILUTIONS OF NICOTINE SULFATE IN CONTROLLING APHIDS ON HOPS.

| TREATMENTS APPLIED JULY 21, 1938 | APHIDS KILLED ON JULY 22, PER CENT |
|---|---|
| Bordeaux, 8–4–100 + Black Leaf "40", 1–800 | 99 |
| Bordeaux, 8–4–100 + Black Leaf "40", 1–1,200 | 98 |
| Bordeaux, 8–4–100 + Black Leaf "40", 1–1,600 | 73 |
| Bordeaux, 8–4–100 | 17 |
| Black Leaf "40", 1–800 + Soap, 3–100 | 97 |
| Black Leaf "40", 1–800 + Soap, 1½–100 | 96 |
| Black Leaf "40", 1–1,600 + Soap, 3–100 | 82 |
| Soap, 3–100 | 30 |

The effect of time of application of the nicotine spray in the control of sooty mold is shown in Table 6. Sprays applied just before the cones grew out were more effective than those applied later. The aphids are more difficult to hit with the spray after they are covered by the cone scales. Nicotine sulfate was more effective when applied as a spray than when used in a dust. Nicotine-lime dusts, containing up to 4 per cent nicotine, were used in three tests and gave a poorer kill than nicotine sulfate used in a spray at 1–800. On the basis of these results, nicotine-lime dust can not be recommended for the control of hop aphids.

TABLE 6.—EFFECT OF SPRAYING WITH BLACK LEAF "40" 1–800 PLUS LIME 3–100 BEFORE AND AFTER THE GROWTH OF CONES ON THE CONTROL OF SOOTY MOLD.

| TREATMENT | DATE OF APPLICATION* | PERCENTAGE OF CONES WITH MOLD AUG. 30 | |
|---|---|---|---|
| | | Total molded | Severely molded |
| | Yard No. 4, 1938 | | |
| Sprayed | July 29 | 9 | 0.3 |
| Sprayed | Aug. 8 | 49 | 2.2 |
| Nonsprayed | ——— | 62 | 8.7 |
| | Yard No. 10, 1940 | | |
| Sprayed | July 25 | 26 | 3.0 |
| Sprayed | Aug. 12 | 48 | 10.7 |
| Nonsprayed | ——— | 60 | 29.2 |

*Cones grew out during the first week in August.

LEAFHOPPERS

The damage done by leafhoppers was demonstrated in 1938 in a hop yard, part of which was sprayed with bordeaux mixture. No diseases developed in the yard, but the leaves in the unsprayed plots were yellowed by hopper feeding and partly killed, as shown in Fig. 3. The sprayed leaves remained green thruout the season. The weight of green hop cones on sprayed plants was 52 per cent greater than on the hopper-burned plants (Table 7). In dry seasons severe leafhopper injury prevented the burs from developing fully into cones.

TABLE 7.—EFFECT OF LEAFHOPPERS IN REDUCING YIELDS OF AN "ENGLISH" CLUSTER HOP VARIETY.

| TREATMENT | PERCENTAGE OF LEAVES INJURED BY LEAFHOPPERS | YIELD OF GREEN HOPS PER PLANT, LBS. |
|---|---|---|
| Bordeaux, 6–4–100 (3 applications) | 4 | 4.3 |
| Bordeaux, 6–4–100 (3 applications) | 2 | 4.0 |
| Nonsprayed | 89 | 3.0 |
| Nonsprayed | 95 | 2.6 |

Leafhoppers appear on hops soon after growth commences. The insects migrate into hops from surrounding fields during late June and July. Attempts to control leafhoppers by dusting with Pyrefume

or spraying with nicotine sulfate failed. Altho kills of 75 per cent were obtained, the leaf hopper populations built up to the original infestations within 3 or 4 days.

FIG. 3.—LEAVES OF AN ENGLISH CLUSTER HOP INJURED BY LEAFHOPPERS.

The superiority of bordeaux mixture and zinc sulfate-lime sprays over certain other fungicides in preventing hopper-burn on leaves of the Millstate hop variety is shown in Table 8.

TABLE 8.—EFFECTIVENESS OF CERTAIN SPRAY MATERIALS IN PREVENTING LEAFHOPPER INJURY ON MILLSTATE HOP.

| SPRAY MATERIALS APPLIED ABOUT JUNE 20, JULY 10, AND JULY 27 | PERCENTAGE OF LEAVES INJURED BY LEAFHOPPERS | | | |
|---|---|---|---|---|
| | 1939 | 1940 | 1941 | 1942 |
| Bordeaux, 6–4–100 | 1 | 0 | 1 | 2 |
| Zinc sulfate-lime, 8–6–100 | 3 | 0 | 1 | 3 |
| Yellow Cuprocide, 1½–100 | 27 | 14 | 23 | 22 |
| Fermate, 2–100 | — | — | — | 12 |
| Spergon (wettable), 4–100 | — | — | — | 43 |
| Copper oxychloride sulfate, 3–100 | — | — | — | 18 |
| Silver nitrate-ferrous sulfate-lime, ¼–½–¼–100 | — | — | — | 8 |
| Nonsprayed | 84 | 51 | 73 | 66 |

## SPRAY INJURY

It was noted that in certain years bordeaux spray visibly injured young hop leaves during cool weather in May and June, while Yellow Cuprocide and zinc sulfate-lime sprays did not cause any visible injury. In order to determine whether there was any difference in the injury as reflected in the yields, these three sprays were applied to the same plots during three successive seasons. The test began in 1941 in a ½-acre yard of 2-year-old plants of the Late Cluster, Millstate, and Brewer's Gold varieties. Replicated plots of 18 plants each were arranged in two Latin squares. Two plots of each variety were sprayed with bordeaux 6–4–100, bordeaux 6–4–100 plus 0.5 per cent cottonseed oil, and Yellow Cuprocide 1½–100. An extra plot of each variety between the Latin squares was sprayed with zinc sulfate-lime spray 6–4–100. All treatments included wettable sulfur 5–100. Sprays were applied thru hand-directed guns.

The test was repeated in 1942 and 1943, applying each spray to the same plots each year. Diseases and insects were not a factor in any of the plots. Yields were obtained in each plot. No significant differences in yields over the 3 years were found between the treatments (Table 9).

TABLE 9.—EFFECT OF CERTAIN SPRAYS ON YIELD OF HOPS SPRAYED WITH THE SAME MATERIALS FOR 3 YEARS.

| SPRAY MATERIAL* | YIELD OF GREEN CONES PER HILL, LBS. | | |
|---|---|---|---|
| | 1941 | 1942 | 1943 |
| Bordeaux, 6–4–100 | 6.6±0.6 | 11.2±0.7 | 4.7±0.6 |
| Bordeaux, 6–4–100+½ per cent cottonseed oil | 6.2±0.6 | 12.5±1.6 | 4.8±0.5 |
| Yellow Cuprocide, 1½–100 | 6.6±0.5 | 11.7±1.7 | 4.8±0.6 |
| Zinc sulfate-lime, 6–4–100 | 6.9±0.3 | 14.1±1.0 | 5.0±0.6 |

*Each spray was applied to six randomized plots, except zinc sulfate-lime which was applied to three nonrandomized plots. All treatments included wettable sulfur 5–100. Four applications were made each year.

### A HOP SPRAY PROGRAM

A simplified program of spraying hops was developed on the basis of the data presented here. The combined spray mixture contains copper to control downy mildew and leafhoppers, sulfur to control powdery mildew, and nicotine to control aphids and sooty mold. The spray schedule given in Table 10 controlled the principal diseases and insects of hops in experimental yards of the Late Cluster and Millstate varieties during the past 4 years. It was effective also when used by growers and is recommended for use in most hop yards, except in large valley yards where severe downy mildew epidemics may require additional spray applications.

TABLE 10.—THE STANDARD SPRAY SCHEDULE FOR NEW YORK HOP YARDS.

| APPLICATION NO. | APPROXIMATE DATE | MATERIALS IN POUNDS IN 100 GALLONS OF WATER | MINIMUM GALLONS PER ACRE* |
|---|---|---|---|
| 1 | June 1–7 | Bordeaux, 4–3–100, or Zinc sulfate-lime, 8–6–100 | 125 |
| 2 | June 20–25 | Bordeaux, 6–4–100, +wettable sulfur, 3–100 | 175 |
| 3 | July 6–12 | Bordeaux, 6–4–100, +wettable sulfur, 4–100 | 250 |
| 4 | July 24–31 | Bordeaux 6–4–100, +wettable sulfur, 5–100, + nicotine sulfate, 1 pint | 350 |
| 5† | Aug. 25–31 | Nicotine sulfate, 1 pint, +1½ pounds soap, + ¼ pound washing soda | 350 |

*With the sprayer traveling in every row to cover both sides of the plant.
†Nicotine should be applied before or during harvest when honeydew is seen on the leaves or when black mold begins to appear in the more mature cones.

### HOW TO MIX THE SPRAYS

To make the combined spray mixture, start with only enough water to cover intake, wash powdered copper sulfate (blue vitriol)

thru the screen and continue filling until tank is about two-thirds full. Then add lime thru screen. The mixture must be agitated as the lime is added. Follow with wettable sulfur and nicotine. If foaming is troublesome, add a pint of kerosene to each 100 gallons. The zinc sulfate-lime spray is made in the same manner, substituting zinc sulfate for the blue vitriol. The copper sulfate is given 2 or 3 minutes (longer in very cold water) to dissolve with the help of agitation before adding lime, in order to prevent the formation of a sludge. Any undissolved copper or zinc sulfate present when the lime is added will remain in the bottom of the tank, weakening the mixture by that amount which is wasted.

Any soap may be used with nicotine sulfate spray. A liquid soap such as potash fish oil soap is most convenient. Soap chips or flakes can be washed thru the screen. Soap powders, however, will often lump and clog the screen.

## METHODS OF SPRAYING

How the spray is applied is as important as what is applied. Of prime importance is to get thoro coverage of the leaves at the top of the plants during July. Two thirds of the spray should be directed to the upper third of the vines. Some of the spray should reach over the tops and drift onto the upper leaves of adjacent rows. The object of this procedure is to build up a spray residue at the top of the plants. This residue will be in position to wash down onto the cones that develop after the last spraying is applied. It has been demonstrated many times that this washing will protect the unsprayed cones from the mildew diseases. If diseased cones are found in a sprayed yard, they are almost always at the top of the poles or wire, whereas in an unsprayed yard the healthiest cones are found at the top.

Until blossoms are about to be formed, it is important to protect the lower parts of the vine, but after the first of July spraying may be restricted to the upper parts where the crop is produced. In spraying with fixed nozzles on booms attached to the sprayer, as shown in Fig. 4, the number and position of nozzles must be changed as the season progresses. For sprays applied in May, one nozzle on either side may be used to spray the crowns, with another to spray the trained vines as well as the poles for some distance above the vine tips. For the first application in June, two nozzles on each side

are sufficient if the spray is directed upward to hit the undersides of the leaves. The second application in June requires three nozzles on a side. The nozzles should point upward at a 55° angle to the

Fig. 4.— Tractor-powered Sprayer Equipped with Fixed Nozzles Applying Bordeaux and Sulfur Spray Mixture During the First Week in July. The growing of hops on poles and twine, as shown here, is common in most New York yards.

horizontal. The sprays applied in July and August require at least three nozzles on a side and one or two on top of the spray boom.

A pump pressure of 350 to 400 pounds was found sufficient for spraying hops, providing the spray reached over the top of the vines. Sprays should be applied, if feasible, in calm weather. By spraying early in the morning and in the evening, much of the wind can be avoided.

## DISCUSSION

The establishment of serious infection by downy and powdery mildews can be materially delayed, making fewer sprayings necessary, by carrying out certain sanitary practices. The value of sanitation as an adjunct to spraying for disease control in hops was demonstrated convincingly, especially in those plantings where the wind and air drainage were restricted. The following sanitary measures were used successfully in reducing infection until spray residues could be built up on the plants: (a) Remove and destroy diseased basal shoots weekly during May and early June, pulling out the yellowed shoots before they become blackened with spores; (b) eliminate leaves and extra growth at the base of plants by "stripping" and "suckering"; (c) train the young vines early and often enough to keep them from touching the ground; (d) remove diseased shoots before carrying out other operations, such as training, suckering, or stripping, but the vines should never be touched when the leaves are wet; (e) burn the mildewed cones and vines as soon as the crop is picked and before the diseased material shatters to the soil; and (f) destroy neglected "wild" hops in the vicinity of the yard.

The effect of crown treatments in the program of controlling downy mildew is insignificant unless sanitation and spraying are carried out to control the secondary infection. The chemical treatment of the crowns reduces the number of diseased shoots, but the extent of control is insufficient to make it any less necessary to carry out the sanitary measures. However, crown treatments are helpful in insuring the growth of a sufficient number of healthy shoots per hill for training up the poles and strings. Crown treatments have never been needed in well-sprayed hop yards of the State.

Obviously, no one spray schedule will fit the special requirements of different seasons and different plantings. The schedule given in Table 10 controlled the most severe epidemics of the mildews and

insects in small yards of Oneida County. This schedule should be intelligently modified to conform to certain conditions as they vary. Some of these conditions include susceptibility and earliness of the variety, severity of disease or insect development due to weather conditions, the location of the yard in relation to wind and air drainage, the density of hop-vine growth, and the size of the planting.

Restriction of air movement or a dense growth of vines hinder disease control by preventing the rapid drying off of the plants following rains and dews. Diseases are more difficult to control in large plantings where they build up to epidemic proportions more quickly than in smaller yards. Leafhoppers, on the other hand, are less troublesome in large plantings.

The Early Cluster variety is very susceptible to downy mildew and should be sprayed at least five times at 10- to 12-day intervals. Early maturing varieties, such as Early Cluster, would receive their last bordeaux application 2 or 3 weeks before spraying is finished on the late varieties, since bordeaux is not ordinarily applied to the cones because of the possible objection to spray residue. The August application of nicotine and soap is seldom needed on early varieties if harvesting is completed by about August 20.

The regular spray schedule may not suffice to control downy mildew in large valley plantings. Under such conditions the applications of spray should be made more frequently. By spraying in every other row, alternating rows between applications, using about two-thirds as much spray mixture as indicated in the schedule on page 14, and by making an application every 10 days, downy mildew can be controlled in the most difficult locations and on the most susceptible varieties without unduly increasing the cost of spraying. Every row should be sprayed when nicotine is used. If the sprayer cannot be used in May and early June because of wet or rough ground, downy mildew may be controlled by dusting with copper-lime 25–75 when the plants are wet. Dusting is a useful addition to spraying also when fungicides must be applied to the cones and when an epidemic outbreak of either mildew disease requires immediate attention. Cuprocide plus sulfur dust 7–93 or Tri-Basic Copper Sulfate plus sulfur dust 15–85 may be used to control both mildew diseases on the cones.

Bordeaux mixture controlled both downy mildew and powdery mildew in experimental yards over a period of 4 years without the

addition of sulfur. General use of bordeaux with little or no sulfur for the control of the powdery as well as the downy mildew must await confirmation of these results in commercial yards.

There is a real need for a hop resistant to downy mildew which can be grown successfully with little or no spraying. This need is especially apparent in plantings too small to justify the expense of a sprayer. Brewer's Gold possesses some resistance and is recommended as a good variety for the grower who is limited to the use of a duster.

## SUMMARY AND CONCLUSIONS

Uncontrolled diseases and insects are a limiting factor in the commercial production of hops in New York State. Experiments were conducted in Oneida County during the past 7 years to develop effective and economical methods of controlling downy mildew, powdery mildew, sooty mold, aphids, and leafhoppers. A spray schedule is presented and modifications of it are discussed.

Sanitation was important in controlling downy mildew in certain valley yards where the disease develops early and rapidly. Elimination of diseased shoots before they sporulated delayed the development of serious infection for over 2 weeks.

Of the copper, zinc, and sulfur spray materials tested for the control of downy mildew, bordeaux mixture was most effective. Red or yellow Cuprocide and zinc sulfate-lime sprays at metallic concentrations of 1½–100 were as effective as bordeaux 6–4–100, except in the protection of the cones against downy mildew. Dusts as used were less effective than sprays. Powdery mildew was controlled by either dusting or spraying with sulfur. It was found that four applications of bordeaux mixture 6–4–100 plus 4 pounds of wettable sulfur dust, beginning early in June and made every 15 to 20 days, gave excellent control of both mildews.

Bordeaux and zinc sulfate-lime controlled leafhoppers more effectively than insoluble copper sprays or Fermate. Nicotine sulfate was added to the bordeaux-sulfur spray mixture whenever it was necessary to control aphids. Nicotine sulfate, used with either bordeaux or soap, as applied in these experiments, was effective at a dilution of 1–1,200. A dilution of 1–800 is recommended for sprays applied thru fixed nozzles. If it is necessary to apply nicotine sulfate in cool weather, a 1–400 or 1–600 dilution is indicated.

Sprays containing bordeaux mixture, Yellow Cuprocide, or zinc sulfate-lime were applied to the same replicated plots for three seasons. Diseases and insects did not affect the yields. The differences in yields between these plots over the three seasons were not significant. It is concluded that any injury that might have been caused by these sprays had approximately the same effect on the yields.